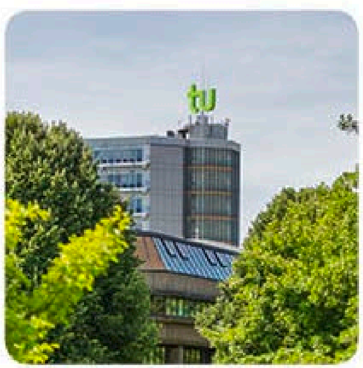
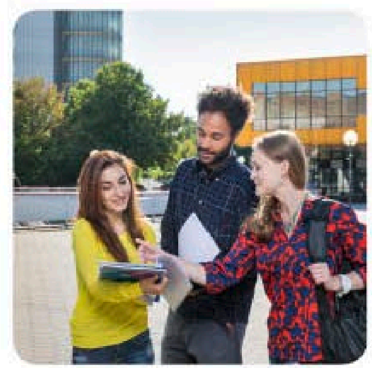
technische universität
dortmund

HFT

Modelling Spectral Hole Burning of EDFA Assuming a Small Number of Distinct Groups of Erbium Ions





Inga L. Rittner and Peter M. Krummrich

10.05.2023

Outline

- Motivation
- Modelling Approach
- Measurement Set-up
- Results
- Summary

Motivation

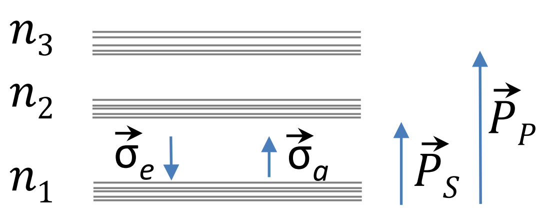
- Adaptation to changing traffic patterns and energy efficient operation may be desired
  ➡ dynamical activation and deactivation of WDM channels

- EDFA are operated in saturation and cause transients

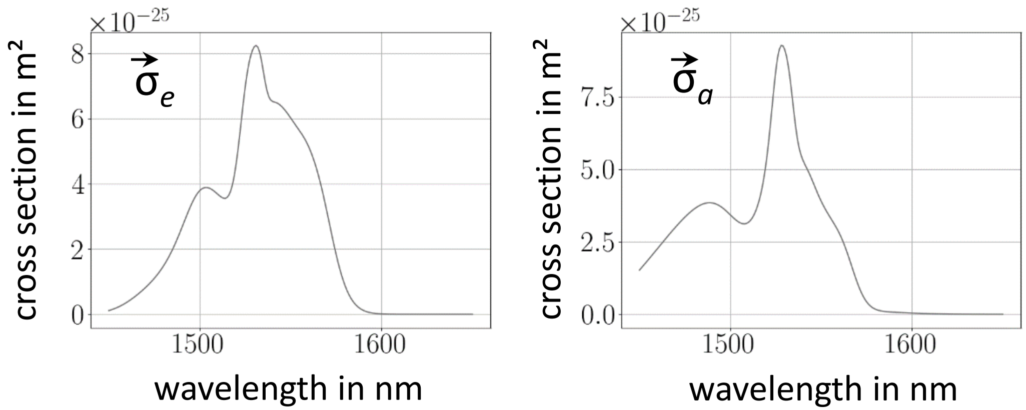
- Enhancement of current EDFA models
  ➡ e.g. spectral hole burning effect

Modelling Approach

EDFA as three-level laser system



$$\frac{d\vec{P}_S}{dz} = \vec{P}_S\,(\vec{\sigma}_e\, n_2 - \vec{\sigma}_a\, n_1)$$



Modelling Approach

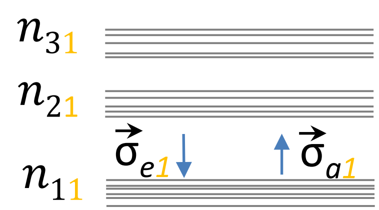
Erbium Ion Groups

$$\frac{dP_S}{dz} = P_S \sum_{i=1}^{M} (\sigma_{ei}\, n_{2i} - \sigma_{ai}\, n_{1i})$$

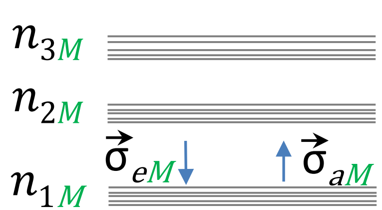
$$= P_S(\sigma_{e1}\, n_{21} - \sigma_{a1}\, n_{11}) + $$

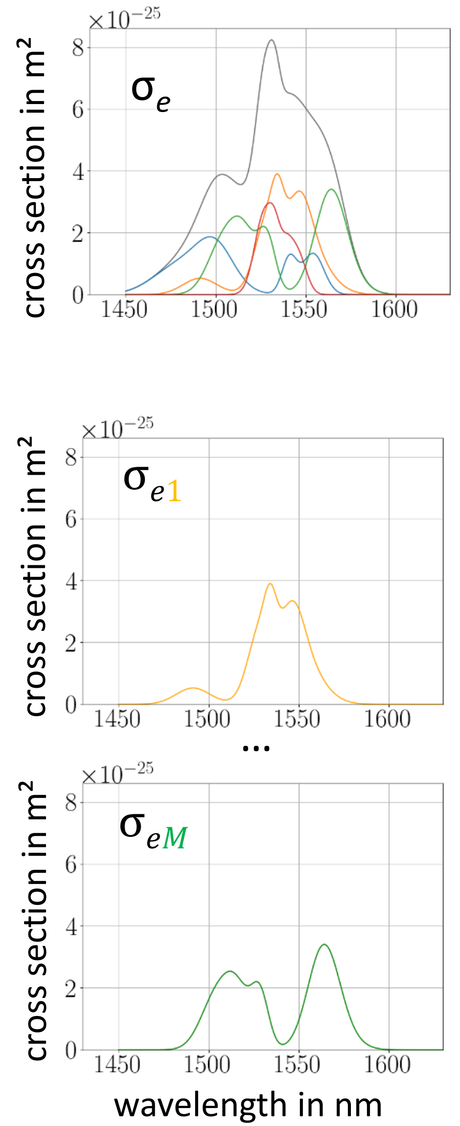
...

$$P_S(\sigma_{eM}\, n_{2M} - \sigma_{aM}\, n_{1M})$$



...





Modelling Approach

Derivation of Cross Sections of Erbium Ion Groups

$$\frac{d\vec{P}_S}{dz} = \vec{P}_S \sum_{i=1}^{M} (\vec{\sigma}_{ei}\, n_{2i} - \vec{\sigma}_{ai}\, n_{1i})$$

$$= \vec{P}_S \frac{1}{M} \sum_{i=1}^{M} (\vec{\sigma}_{ei}\, n_2 - \vec{\sigma}_{ai} n_1)$$

$$\approx \quad \vec{P}_S (\vec{\sigma}_e\, n_2 - \vec{\sigma}_a\, n_1)$$

$$n_{1i} = \frac{n_1}{M}$$

$$n_{2i} = \frac{n_2}{M}$$

$$\sum_{i=1}^{M} \vec{\sigma}_{ei} \approx M\, \vec{\sigma}_e$$

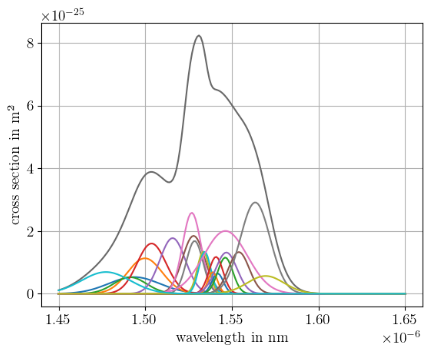
$$\sum_{i=1}^{M} \vec{\sigma}_{ai} \approx M\, \vec{\sigma}_a$$

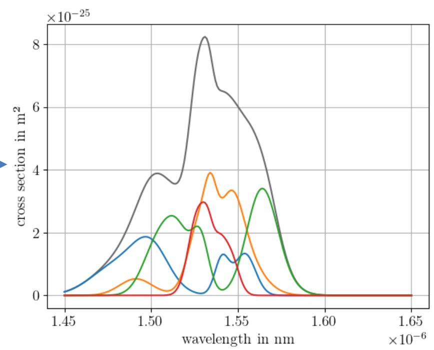
Modelling Approach

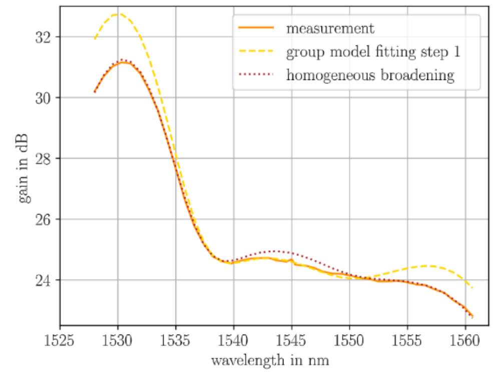
Fitting of Cross Section Spectra of Erbium Ion Groups

M = 4

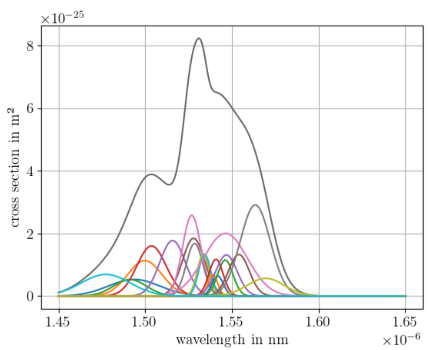
Step 1 $M\,\vec{\sigma}_e\,,\ M\,\vec{\sigma}_a$

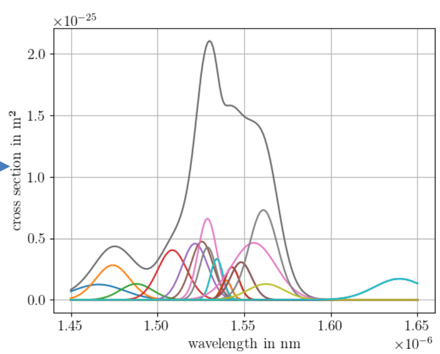


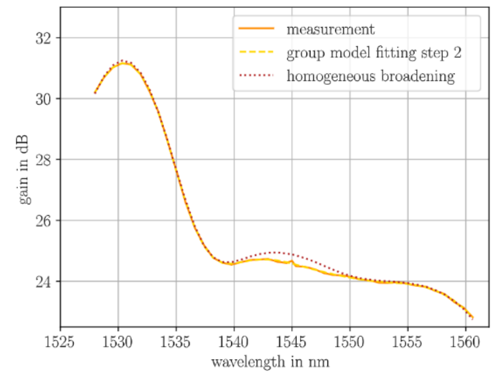




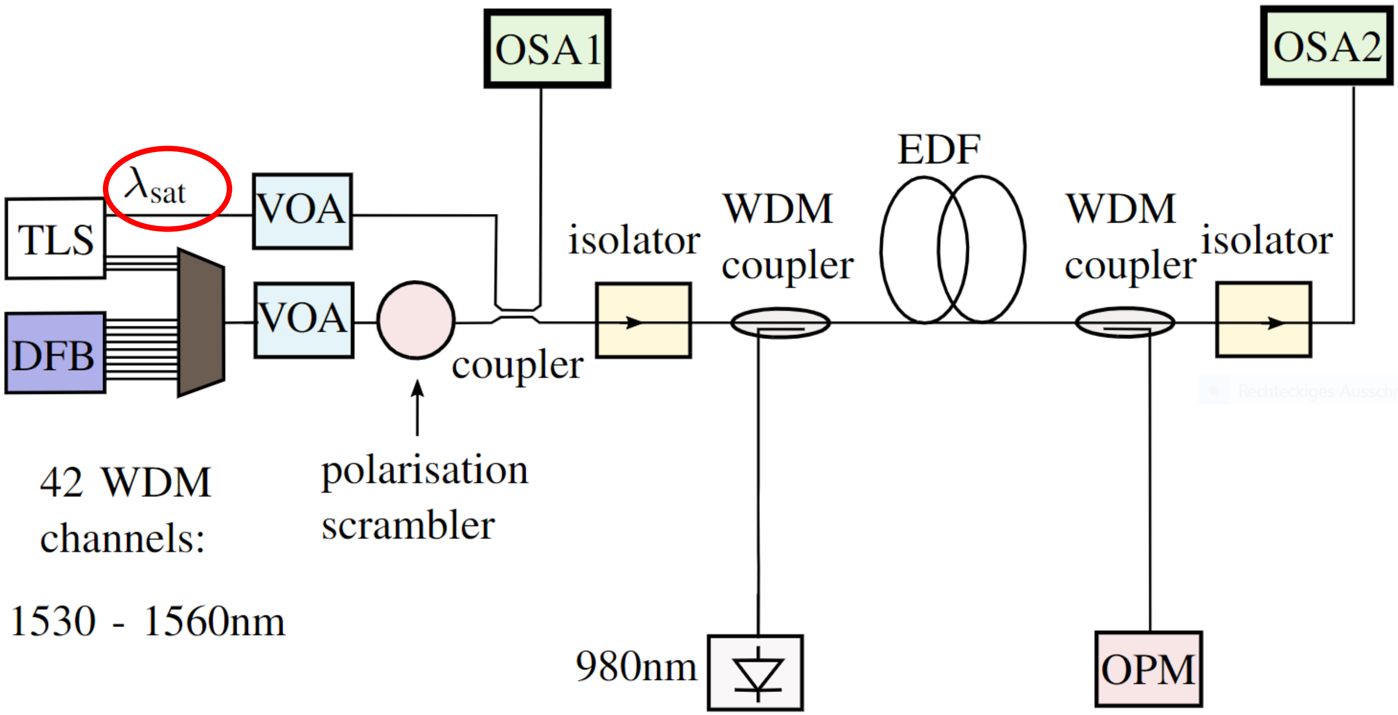
Step 2 $M\,\vec{\sigma}_e \rightarrow M\,\vec{\sigma}_{eII}$





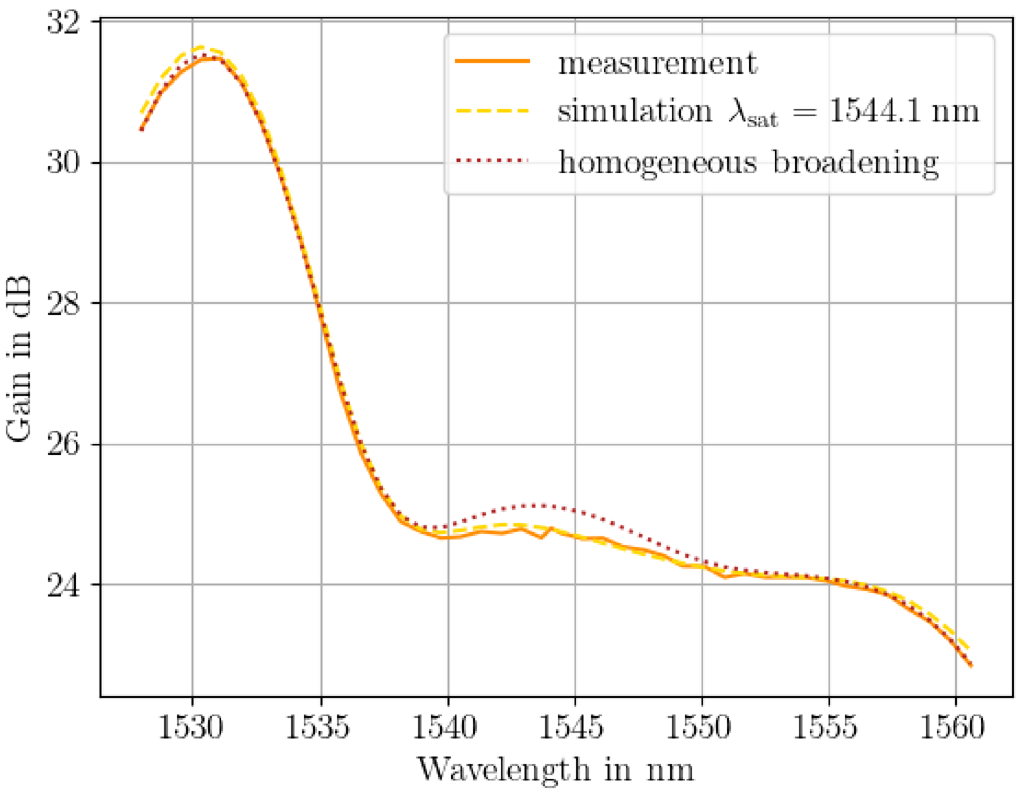


Measurement Set-Up



Results

Erbium ion group model approach fitted at λ_{sat} = 1545nm shows decent agreement for λ_{sat} = 1541.7 – 1547.3nm



	Parameter	Value	Unit
	WDM signal	1527.99 - 1560.61	nm
	λ_{sat}	1544.1	nm
	$P[\lambda_{sat}]$	≈ -4.9	dBm
	M	4	
Model fitting	λ_{sat}	1545	nm
	w_1	≈ 16	nm
	L	20	
	$\Sigma_{\mathrm{Indices}_i}$	$45 - 50$	

Summary

- Modelling approach for the spectral hole burning was presented
- Erbium ions contribute differently to the gain spectrum depending on the site they occupy
- Measurement results are used to fit the modelling approach in a two-step procedure
- The fitting procedure was performed for a saturating channel at $\lambda_{sat} = 1545nm$
- The model shows decent agreement for saturating channels with $\lambda_{sat} = 1541.7 – 1547.3nm$